DOCUMENT RESUME

ED 413 961 JC 980 014

AUTHOR Gaddis, Tony
TITLE Using Virtual Reality To Bring Your Instruction to Life.
PUB DATE 1997-10-00
NOTE 25p.; Paper presented at the League for Innovation Conference on Information Technology (Atlanta, GA, Oct. 12-15, 1997).
PUB TYPE Guides - Classroom - Teacher (052) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *College Instruction; Community Colleges; Computer Peripherals; Computer Selection; *Computer Simulation; Educational Planning; *Educational Technology; Program Development; Teaching Guides; Technological Advancement; Two Year Colleges; *Virtual Reality

ABSTRACT

Prepared by the manager of a virtual reality (VR) laboratory at North Carolina's Haywood Community College, the three papers collected in this document are designed to help instructors incorporate VR into their classes. The first paper reviews the characteristics of VR, defining it as a computer-generated simulation of a three-dimensional environment, the contents of which can be viewed and manipulated by users. This paper also discusses the range of immersion that users can feel in the environment and methods for achieving that immersion, methods for tracking user and environment position and orientation, VR input devices, the use of sound and tactile feedback, and professional applications of VR. The second paper describes the following steps in planning a VR system: (1) defining the desired application--including the level of immersion desired, viewing and input devices, and position and orientation tracking capabilities; (2) assessing institutional resources and capabilities; (3) choosing VR development software, taking into consideration geometry creation and editing, programming requirements, peripheral and network support, system requirements, and portability; and (4) selecting appropriate hardware to manage peripheral devices, such as graphics cards, head-mounted displays, and tracking devices. The final paper describes VR courses taught at HCC, reviews past projects, and discusses current and future VR development. A list of Web addresses for VR-related companies is attached. (BCY)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 413 961

Using Virtual Reality to Bring Your Instructiom to Life

Tony Gaddis

Paper presented at the League for Innovation Conference on Information Technology
(Atlaanta, GA, October 12-15, 1997)

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

PERMISSION TO REPRODUCE THIS
MATERIAL HAS BEEN GRANTED BY

T. Gaddis

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC).

JC 980 014

BEST COPY AVAILABLE

Using Virtual Reality To Bring Your Instruction to Life

Presented by
Tony Gaddis
Coordinator of Advanced Technology
Haywood Community College
Regional High Technology Center
tony@haywood.cc.nc.us

What is Virtual Reality?

Tony Gaddis
Haywood Community College
©1995, 1997

As the manager of a virtual reality lab, I am frequently asked the question "what is virtual reality?" I have noticed those who ask the question rarely stumble on their words. They are very comfortable with the term, *virtual reality*, which seems to indicate it has found its way into the vocabulary of our culture. At the same time, its meaning seems to be universally unclear. Indeed, virtual reality is a household term without a definition.

Much of the mystery has been caused by the media, which usually focuses on the potential of VR instead of the actual state of the technology. The potential represented in movies, television, and works of literary fiction is sometimes real, but more often imagined. Within the past year, I have seen virtual reality portrayed as a gateway to the unconscious mind, a tool for expanding brain capacity, and the key to immortality. It is romanticized as a synthetic world that, once entered, is indistinguishable from natural reality. Fictional characters have even become trapped in virtual worlds, with no way of escape.

None of this, of course, should come as a surprise. The fictionalized state of virtual reality makes for far better entertainment than the actual state. Today's VR systems, although capable of generating surprisingly realistic and useful virtual worlds, cannot begin to accomplish the feats dreamed of in Hollywood. Unfortunately, the general public doesn't know that. Even after recognizing the obvious sensationalism of television and film, it is difficult for the average person to even guess what VR is actually capable of. Most individuals have never experienced virtual reality. Their only frame of reference is the media's images of the cybernaut, wearing her fully enclosed head-mounted display, fiber-optic glove, and wired body suit. Without having an actual experience to associate with these images, VR naturally becomes a mysterious technology.

The search for VR's meaning is not limited to the movie-going public. Even among the scientists, academicians, and journalists who regularly contribute to this field, there is a difference of opinion. The debate among the practitioners seems to be more about what VR is not, instead of what it is. Some insist that VR only includes those systems that produce multi-sensory experiences, where natural reality is completely blocked out and replaced by synthetic three-dimensional images, sounds, and other sensations. There are others, myself included, who place the boundaries of VR much further out, to include desktop computers that display three-dimensional graphical worlds on standard computer screens.

There are many who say VR doesn't have to include graphical systems. They include text-based systems, like Internet Multi-User Dungeons (MUDs) and the venerable *Adventure* game in the definition of virtual reality. I, personally, prefer not to categorize these with graphical VR systems. Although the virtual worlds of text-based systems may be rich in detail, they are constructed within the imagination and do not require computer graphics hardware or software.

Since so much of the work taking place within the field of VR centers around graphics generation, it seems to me that text-based systems deserve a separate and distinct field of their own.

For the purposes of this paper, let's agree on a working definition of virtual reality that describes only graphical systems. According to the American Heritage Electronic Dictionary, the term virtual is defined as "existing in effect or essence though not in actual fact or form," and reality is defined as "something that is real." The two definitions, obviously, are in conflict. Is there any wonder VR is shrouded in mystery?

Instead of wrestling with the incongruities of an oxymoron, let's consider virtual reality strictly as a computer term. Turning, then, to Que's Computer User's Dictionary, 3rd Edition, the definition of virtual includes the following statement:

> . . . the on-screen representation of a computer entity or object that does not exist.

Virtual reality, then, can be considered a reality simulated by objects on a computer screen. Reality implies realism, so the objects are expected to have characteristics that cause them to behave, or simply exist, in a realistic manner. We experience reality through sensory input, so we must be able to perceive the objects in a virtual reality system through at least one of our senses (Stampe, Roehl, and Eagan 10). Stampe, Roehl, and Eagan present a definition that I feel adequately describes virtual reality:

> A computer-generated simulation of a three-dimensional environment, in which the user is able to both view and manipulate the contents of that environment (9).

There are three critical ideas present in this definition:

- VR is computer-generated
- It is a simulation of a three-dimensional environment the user is able to view
- The user is able to manipulate, or interact, with the contents of the environment

Let's examine each of these components.

VR is Computer-Generated

Virtual reality is computer-generated. Astonishingly, though, the roots of VR technology predate the computer. In 1929 the first flight simulator, called the Link Trainer, was patented. It was an airplane cockpit mounted to a pneumatically-controlled motion platform. Pilots controlled it with a stick just like an actual plane. The motion platform moved in response to the actions of the pilot, who watched a horizon line shift and move. Later versions of the Link Trainer incorporated movie projectors to give the pilot a more realistic view (Rheingold 203).

Other attempts at creating vicarious experiences through non-computer technology are found in

the field of entertainment. In the 1950s the innovative Cinerama was created. Viewing three synchronized films displayed on a wrap-around screen, audiences experienced movies with a field-of-view of almost 180 degrees (Pimentel and Teixeira 37). In the 1960s the cinematographer Morton Heilig created a mechanical device known as the Sensorama. Resembling an arcade game, the Sensorama had a seat, handlebars and an aperture for viewing three-dimensional films. The customer sat in the seat and experienced sites, sounds, smells, and vibrations in a simulated motorcycle ride (Pimentel and Teixeira 39).

Each of these early attempts were successful at creating simulated experiences with a little or no interaction. The Cinerama and Sensorama audiences were subject to increased sensory input, but the experience was passive. The Link Trainer responded to interaction, but its functionality was limited. Only the modern computer is powerful and flexible enough to create truly interactive virtual realities.

It is a Simulation of a Three-Dimensional Environment the User Is Able To View

An important objective of a virtual reality system is to create a simulated three-dimensional space, known as a virtual world. This space becomes the setting for specific activities, such as surgical training, or the reconstruction of an ancient city. The objects that populate the 3D space are designed to support the theme of the virtual world, and to play a role in the world's overall purpose. These objects are provided for human viewing and interaction, so they must have a 3D appearance.

The User Is Able to Manipulate, or Interact, With the Contents of the Environment

Being able to move a viewpoint within the virtual world, as if "walking around," is the simplest form of interactivity. The objects in the virtual world may be viewed from any location within the virtual space. This, of course, is subject to the design limitations of the virtual world. It may be necessary for some worlds to impose restrictions on where the user is allowed to move to, and from what angles certain objects may be viewed. These limitations would only exist to serve the specific purposes of the virtual world.

In addition, virtual worlds commonly provide a method of interacting with the individual objects that populate it. For example, a physics instructor might employ a VR system to demonstrate the speed at which objects fall on different planets. The hypothetical system would allow the instructor to assign different constants of gravitational acceleration to different objects. By simulating the ability to actually pick these objects up and drop them, the instructor may visually demonstrate the material of his lecture.

Immersion

The user of a VR system becomes immersed in the virtual world when he or she feels "in" the 3D environment, or surrounded by it (Rheingold, 100). Immersion has always been an important goal, if not the primary objective, in many VR systems. In fact, it was the motivation behind such

historical developments as the Link Trainer, Cinerama, and Sensorama. Creating a sense of immersion usually requires specialized equipment to block out the sensory input of the natural surroundings and substitute it with computer-generated stimuli. This equipment includes the head-mounted display, wired glove, and other devices often depicted in movies.

In my experience, the degree that one feels immersed is subjective. I have created immersive virtual worlds that caused some users to react with amazement to the sense of presence they experienced. Others, however, reported little or no sense of immersion. Also, the users who report a greater sense of immersion usually describe the virtual worlds as being more realistic in appearance than do those who sense little immersion.

This is not to say the users who sense greater immersion gain more from the experience than those who sense little immersion. Some individuals are simply more willing to suspend disbelief than others. Because of this observation, VR designers should not strive to create highly immersive worlds merely for the sake of a realistic experience. In fact, many VR systems should not be immersive. A simple desktop computer which displays graphics on a monitor is sufficient for many situations. These non-immersive systems provide a "window" through which the user observes the virtual world (Gaddis 12).

The Immersion Spectrum

The degree of immersion sensed by a user depends on a large number of factors, many of which are discussed in this paper. At the low end of the immersion spectrum are simple desktop systems. As mentioned before, these systems display the virtual world on a computer monitor. These systems are controlled with typical input devices, such as a keyboards and mice. The further we travel up the immersion spectrum, the more complex and expensive the systems get. At the high end, we find systems costing millions of dollars, utilizing graphics supercomputers, custom-built displays, and an array of other devices (Gaddis 12).

Most VR systems, however, fall somewhere between these two extremes. In fact, I predict the cost-efficiency and usefulness of non-immersive VR, coupled with coming technological advancements, will create a great demand for low-end systems.

Visual Immersion

For most, the term "virtual reality" conjures up an image of a somewhat entranced person wearing a head-mounted display, or HMD. In some ways, an HMD is similar to a space helmet. Both are firmly attached to the head. Both allow the wearer to leave one environment and enter another. An HMD, however, functions more like a reverse space helmet. Instead of protecting the wearer from too much immersion, as the space helmet does, an HMD provides greater immersion. It blocks out the view of the natural surroundings and displays a view of the virtual world.

Monoscopic Vs. Stereoscopic HMDs

Simple, inexpensive HMDs are equipped with a single liquid crystal display (LCD), placed near the eyes. The effect is similar to sitting very close to a television set. These units are referred to as *monoscopic* HMDs, because they can only present a single image to both eyes. *Stereoscopic* HMDs have two LCDs, or other display surfaces. This gives them the ability to display a different image to each eye, which is necessary to produce a three-dimensional scene. The computer calculates the angle that each eye views the virtual world from, and generates two images based on those viewing angles. When the right-eye image is presented to the right eye, and the left-eye image is simultaneously presented to the left eye, the brain is tricked into perceiving a three-dimensional scene.

Field-Of-View

The human lateral field-of-view (FOV) is approximately 180 degrees. This does not include the extra 45 degrees that each eye may be pivoted. Given the total 90 degrees of pivotal movement, humans get some level of visual input from as much as 270 degrees of the environment immediately before them (Aukstakalnis and Blatner, 70).

The more of the FOV that the image of the virtual world can fill, the more immersive the experience will be. Ideally, the entire 270 degree potential FOV should be filled with an image of the virtual world. Given current optical and display technology, this is hardly possible. Simple LCDs placed close to the eyes will produce seemingly large images, but they will not fill a dominate portion of the FOV. Even with optics to magnify the displays, many HMDs can only fill 30 to 45 degrees of the FOV. Some VR display systems command much more of the FOV, but at a substantial cost.

Stereoscopic Goggles

Stereoscopic goggles, sometimes referred to as "shutter" goggles, are used to view stereoscopic images on desktop computer monitors. Similar to a heavy pair of glasses, the user looks through clear panels. Instead of being lenses, however, the panels are actually clear LCDs. They have the ability to quickly darken, or shutter.

The left and right-eye images are rapidly displayed, one after the other, on the computer screen. When the left-eye image is on the screen, the right panel in the goggles is darkened. Only the left eye sees the image. The reverse happens when the right-eye image is displayed. The result is that the user perceives a three-dimensional image coming from the monitor.

Early Work in HMD Technology

HMDs are not recent innovations. Ivan Sutherland developed the first HMD in 1968 at Harvard University. The display, known as the "Sword of Damocles," generated stereoscopic wireframe images that were reflected onto two see-through panels. The graphics seemed to overlay the

user's view of the natural surroundings (Aukstakalnis and Blatner, 81).

Position and Orientation Tracking

If a VR system allows an immersed user to perform movements, such turning his or her head to look around, the system must track these movements and update the view of the virtual world accordingly. Not only must movements of the head be tracked, but also those of any body part that is to be present in the virtual world. For example, if a world allows the user to grasp virtual objects in his or her hand, a special glove must be used to monitor the positions of the fingers. This alone is not enough, however. Finger movement is but one action of the hand. The user is also capable of elevating the hand, moving it from side to side, tilting it, etc. A separate tracking device must be used to sense these types of movement and relay the data back to the computer.

Six Degrees of Freedom

There are basically six types of movement possible in three-dimensional space. Imagine the ways a person's head may move. First, linear movement is possible. By squatting down and standing up, a person's head moves up and down. By stepping sideways to the left and to the right, a person's head moves left and right. By stepping forward and backward, a person's head moves forward and backward. So, the three types of linear movement are up/down, left/right, and forward/backward. These movements may be modeled by a Cartesian coordinate frame with X, Y, and Z axes.

The remaining three movements are rotational. Imagine a person tilting his or her head up and down, as if slowly nodding "yes." This rotational movement is called pitch. When the head turns left to right, or vice versa, the movement is called yaw. Finally, when the head is tilted sideways, the movement is called roll. The three types of rotational movement, or orientation, are pitch, roll, and yaw.

Magnetic Tracking Devices

Magnetic sensors are probably the most popular devices for tracking movement. They are small and can track all six types of movement. Magnetic trackers use a transmitter, which sequentially emits three magnetic fields. The user, who stands within the magnetic fields, wears a small receiver containing three coiled wires. The magnetic fields induce voltage in the coiled wires of the receiver. This produces a total of nine measurements, which can be used to calculate the sensor's position and orientation (Pimentel and Teixeira 196).

Mechanical Tracking Devices

These types of trackers are usually mechanical arms with one or more rotating joints. They typically attach to a HMD, and contain encoders in the joints which measure movement. These trackers are also capable of sensing all six degrees of movement (Pimentel and Teixeira 199)..

Ultrasonic Tracking Devices

Ultrasonic trackers employ an array of three emitters that sequentially send out pulses of high frequency sound. The user wears an array of three receivers, or microphones. By measuring the amount of time each sound pulse took to arrive at each of the receivers, position and orientation data may be calculated (Pimentel and Teixeira 198).

Other Tracking Methods

Although magnetic, mechanical, and ultrasonic are the most commonly used methods of tracking position and orientation, other technologies exist. Inertial tracking, for example, uses tiny gyroscopes to measure pitch, roll, and yaw. Optical systems that use image processing software have been used to track infrared LEDs, or other visually detectable targets worn by the user. (Pimentel and Teixeira 199). Image extraction is a promising technology that most certainly will be used in the future. One or more video cameras monitor the user while image processing software on powerful computers analyze the images to determine position and orientation (Aukstakalnis and Blatner, 36).

VR Input Devices

Besides sending commands to the system, input devices are used to navigate the virtual world and interact with the objects that populate it. Mice have evolved as the most popular input device for interfaces like Windows, which present a two-dimensional space for the user to work in. Virtual worlds, however, are three-dimensional work spaces. Mice are commonly employed in desktop VR systems, but the user normally toggles between different modes of operation. For example, in one mode the mouse may be used as a navigational tool. As the mouse cursor is moved to different regions on the screen, the viewpoint is moved within the world. In another mode the mouse might be used to select and move objects.

Flying Mice

Some companies have produced mice that may be readily used in three-dimensional worlds. With an accompanying tracking device, they may be lifted off the desktop to control an object or cursor in the virtual world (Gaddis 13).

Isometric Devices

Isometric devices are popular because they are intuitive to use. They are equipped with a ball or puck-like tool that the user grasps in his or her hand. The tool may be moved around like a joystick, twisted, pressed down, or pulled up. The amount of force and torque exerted on the tool is measured (Gaddis 13).

Wired Gloves

The primary purpose of wired gloves is to monitor the articulation of the user's fingers. This is necessary for any system that allows the grasping of virtual objects. Some systems have been developed that understand hand gestures. Pointing a finger, for example, might be interpreted as a command for flying (Gaddis 13).

3D Sound

Humans have the ability to localize sound within a three-dimensional environment. We can determine if the source of a sound is located behind us, in front of us, to the left or the right, above or below. If a virtual world contains an object that emits sound, special challenges are presented. Computer sound cards with simple stereo headphones cannot produce 3D sound. Special equipment consisting of digital signal processing hardware is necessary to simulate, through headphones, sound coming from any location in the three-dimensional environment.

Tactile and Force Feedback

Without some sort of physical sensation, VR practitioners must rely on visual and audible cues to indicate they have made contact with a virtual object. For example, it is difficult to know exactly when a virtual hand touches another object. When the user sees part of the hand actually engulfed inside the object, it is visually obvious that contact has been made. Also, some systems might generate audible "pings" to indicate that contact has been made.

To create the sensation of touch in a virtual world, many clever systems have been developed. These systems generally fall into one of two categories: tactile feedback and force feedback. Tactile feedback devices apply force to the surface of your skin. They are necessary to simulate the feeling of an object's surface. Force feedback devices apply force to your muscles, simulating the pull of gravity, or the resistance of an object you are pushing.

Tactile feedback devices commonly use tiny vibrators or air bladders to create localized pressure on the skin. For example the Teletact glove has an array of twenty air pockets around the palm-area of the hand. The pockets that may be quickly inflated to create pressure on the underside of the hand, simulating physical contact with an object (Pimentel and Teixeira 174).

At the University of North Carolina at Chapel Hill, scientists use a force feedback device to feel the attractive and repulsive forces at work in molecular docking. A mechanical arm that hangs from the ceiling is used to manipulate virtual molecules, while pushing and pulling the user to simulate molecular forces (Aukstakalnis and Blatner, 146).

Applications of VR

Most people still associate entertainment with virtual reality. Although entertainment has been a major application area of virtual reality, it is hardly the sole province of VR. Virtual reality has

been used to create a wide variety of professional applications in the following fields:

- Engineering and Design
- Architecture
- Medicine
- Visualization
- Marketing
- Network Communications
- The Arts
- Education, Training, and Simulation
- Space Exploration
- Mathematical Modeling
- Telerobotics
- Health and Fitness
- Acoustical Evaluation

Works Cited

Aukstaklnis, Steve, David Blatner. Silicon Mirage: The Art and Science of Virtual Reality. Berkeley: Peachpit Press, 1992.

Gaddis, Tony. "Planning Your Virtual Reality Lab." VR in the Schools Nov./Dec. 1995

Pimentel, Ken, Kevin Teixeira. Virtual Reality: Through the New Looking Glass. New York: Intel/McGraw Hill, 1995

Rheingold, Howard. Virtual Reality. New York: Touchstone, 1991.

Stampe, Dave, Bernie Roehl, and John Eagan. Virtual Reality Creations. Corte Madera: Waite Group, 1993.

Planning Your Virtual Reality Lab

Tony Gaddis
©1995, 1997

Today, the virtual reality industry resembles the personal computer industry in its early years; there are many products, but few come with everything a buyer needs. Because the price of putting together a VR system has dropped considerably in the past few years, many schools are finding themselves in a position to start a VR lab. Putting together a VR lab requires a good bit of pre-purchase planning, particularly with immersive systems. Although the prices continue to drop, VR systems are still costly enough that mistakes can be traumatic, and financially recovering from those mistakes is sometimes difficult. Whether your lab is to have one system, or an entire roomful, the purpose of this article is to point out not only the obvious, but many of the hidden pitfalls that can send you scrambling for extra dollars to complete your project.

Define the Application

The first step in planning a VR system is to define the application you wish to create with it. It is important to begin with a clear vision of the system and how it will work. The virtual world you wish to build should be visualized, along with all the devices that will be used to view, navigate, and interact with the environment. The behavior of objects in the virtual world must be planned, as well as all the ways the user will be able to manipulate them. It is from this picture that you will be able to determine the features of your application and the capabilities of your system. Here are some specific things to consider while forming this vision.

Immersion

The sense of immersion that is created by a VR system largely depends upon the amount of sensory input it is capable of providing. At one end of the immersion spectrum are desktop systems that display monoscopic views of the virtual world on a monitor. At the opposite end of the spectrum are highly immersive systems with stereoscopic head-mounted displays, position and orientation tracking devices, and other specialized peripherals.

Not all applications are best served by the same level of immersion. Some work just as well at the low end of the spectrum as they do at the high end. If it does not detract from the quality or functionality of the application to have the view of the virtual world confined to a computer monitor, decide on a non-immersive system with robust development software. If your application demands immersion, however, you will need to carefully choose the combination of hardware and software that will fit your budget and come as close to your original vision as possible. Since the cost and complexity of VR systems goes up dramatically as the level of immersion increases, it is important to find your application's ideal location in the spectrum.

Viewing Devices

At the mere mention of the term "virtual reality," the image of a person wearing a head-mounted display usually comes to mind. Despite the fact that it has become the icon of VR, the head-mounted display is not the only VR viewing device to choose from. Head-coupled displays, shutter goggles, and viewing hoods are also available. A comparison of each of these devices can be helpful.

- Head-mounted displays block the view of the real world and present the user with the computer-generated images of the virtual world. They are usually strapped onto the head

so the display turns as the user looks in any direction. Head-coupled displays do not strap or fasten to the head. The user observes the virtual world by looking through eyeholes on a box that house the displays. Head-coupled displays are convenient because the user can easily look away to access the keyboard or mouse. Many of them have the added benefit of being mounted to a mechanical arm that not only counterbalances the weight of the display, but also provides position and orientation tracking.

- If stereoscopic images are desired, but a high level of immersion is not critical to your application, shutter goggles are what you want. Rather than presenting the user with two separate display panels (like a head-mounted display), shutter goggles allow stereoscopic images to be displayed on a desktop computer monitor. The left and right eye images are very rapidly displayed, one after the other. The user wears a pair of goggles that use two clear LCD panels for lenses. The goggles filter the images by darkening the panel over the right eye while the left eye image is on the screen, and then darkening the panel over the left eye while the right eye image is on the screen. Since the user can still see the surrounding room, the sense of immersion is not as great. The quality of the graphics, however, is usually much higher since they are being displayed on a computer monitor.

- Viewing hoods are enclosures that attach to the front of a computer monitor and provide optics and eyeholes for the user to look into. Essentially, the monitor is converted into a stereoscopic head-coupled display, but without the benefit of position or orientation tracking.

Tracking Capabilities

The next option to consider is the type of body movements your system should track. Some applications only require tracking of the rotational movement of the head. If this is the case, a simple 3 degree-of-freedom (3-DOF) tracker, which senses pitch, roll, and yaw, will be sufficient. A 3-DOF tracker attached to a head-mounted display senses the direction the user's head turns, but it does not detect the change in height of the head as the user bends over, or the change in position as the user walks around. Systems that use 3-DOF tracking are common, and usually require the user to "fly" around in the virtual world with a joystick (or other handheld device) while changing the angle of the viewpoint by turning the head.

If your application must allow more freedom of movement, like the ability to stoop under virtual desks and walk around virtual objects, you need a 6 degree-of-freedom (6-DOF) tracker. These trackers sense both rotational and linear movement, detecting the direction the head-mounted display is turned and any change in its position.

You should also be aware of how many tracking sensors you will need. A single sensor can track the part of the body it is attached to. If the system needs to track the movement of the user's head and hand, you will need two sensors.

Input Devices

The user will need to navigate in the virtual world and interact with the objects that inhabit it. A variety of input devices are available for VR applications, and you should choose the one which is most appropriate for your needs.

- Although mice work best with 2D interfaces, like GUI's, they can also be used in VR applications for navigating and selecting objects. There are even mice that have 3-DOF or 6-

DOF tracking capabilities. Once these mice are lifted off the desk, they can be used to control an object or cursor within a 3 dimensional virtual space.

- Since movement in the virtual world is not unlike flying, a simple joystick might be all you need. In addition to navigating by pushing and pulling the stick, joysticks also provide buttons which can be programmed to perform other functions.

- Isometric devices are popular among VR designers because they are intuitive to use and can control movement with 6 degrees-of-freedom. The user's hand grasps a ball or puck-like instrument and simply moves it in the desired direction. The device works by measuring the amount of force and torque being exerted on it.

- Wired gloves are appropriate for sensing the articulation of the user's fingers. If the user wants to touch virtual objects and manipulate them with by hand, a glove device is desired. A glove might also be considered if your application is to follow gestural commands for navigating. Pointing, for example, might be a command for flying, while making a fist might indicate a desire to stop moving.

Assess Your Resources and Capabilities

Your VR system will be a tool for building and experiencing virtual worlds, a task demanding many specialized skills. The graphical objects that inhabit the virtual world must be constructed using a 3D design package. The textures that make virtual worlds life-like must be created, either from digitized photographs or rendering software or must be drawn by someone with artistic capabilities. The programming that gives action to objects in the virtual world and brings life to the simulation must be created by someone with programming skills. The extent of your capability to perform these tasks will greatly influence your decision of which VR development software package to buy. Take a careful inventory of the technical expertise and resources that are available to you.

Choose Your VR Development Software

Choose the right software for the job; then select the hardware. That's good advice for any computer application, including the development of virtual worlds. VR development software comes in various levels of complexity, capabilities, and price. Weigh a number of factors when making the decision. Here are some of the most important considerations.

Geometry Creation and Editing

When selecting a package, one of the first things to consider is the supported method of creating graphical entities. Some packages provide a drawing editor, with all the necessary tools for constructing 3D objects. Others, however, require that the geometry be imported from an external graphics program. In many cases the geometry will already have been constructed with a CAD program and it will be preferable to import it into the VR software. Be sure you know how your virtual world will be drawn and what options for importing geometry you will have with each package.

Programming Requirements

Another important consideration is the level of programming expertise required. For doing anything beyond a simple walk-through, constructing a virtual world usually requires some form

of programming. In some packages, virtual worlds are programmed with simple scripting languages, while in others, all the work is meant to be done with a traditional programming language like C or C++. If the package uses a scripting language, it should come with everything necessary to test and use your virtual world. If the package uses a traditional programming language, however, you'll need to know which compiler it supports. You'll also need to determine if any additional programming tools are required.

Texture Creation and Editing

As mentioned before, textures add more realism to objects in the virtual world. For example, a digitized photograph of a brick wall might be applied to the side of a virtual house. The VR software that you choose will require that textures be stored in a specific graphic file format like TIFF or TARGA. The external graphics program used to create and save textures must be capable of saving images in the supported file format.

Stereoscopic Viewing

Most immersive VR applications use a stereoscopic viewing device. This feature allows two separate images, rendered from slightly different angles to be presented to each eye, creating a 3 dimensional scene. If you plan to use such a device, determine how stereoscopy is accomplished with any software package you consider buying. Simply asking the salesperson if the software allows stereoscopic viewing is not enough. Some packages support stereoscopic goggles, but not head-mounted displays.

Modeling of Physical Behavior

Not all development packages provide simulation of physical laws. If the application demands accurate behavior based on the laws of gravity and other principles of physics, determine which packages provide built-in support. If a package does not provide this support, you will have to develop it yourself through programming, which could require more work and expertise than you can provide.

Peripheral Support

Before purchasing a VR package, check out all of the hardware devices that it supports. If your heart is set on using a wired glove, for example, you'll obviously need to select software that supports such a device.

Also determine if the software supports all of the features of the devices you intend to use. For example, a number of stereoscopic head-mounted displays with integrated head tracking recently have become available. If a software package lists that it supports a head-mounted display, do not assume that it supports stereoscopic viewing and/or head-tracking.

If the software package does not support all your peripherals, you will have to go through the trying experience of writing your own device driver, which means finding out how easily that can be accomplished and what software development tools are required.

System Requirements

Obviously knowing the minimum hardware requirements for any software you buy is essential. Remember, the minimum requirements are usually just that -- minimum. That means the application will run with minimum speed and minimum realism. Describe your application to the software vendor and ask what would be acceptable in terms of processor, speed, amount of memory, and operating system.

Portability

Portability will be an important issue if you intend to use your application on different hardware platforms or operating systems. A development package with a high degree of portability will provide a future upgrade path and give greater flexibility in distributing the application for others to use. If you foresee the need to run the application on systems other than the original development platform, investigate the portability options provided by each development package you consider.

Network Support

The ability for multiple participants using different computers to enter the same virtual world offers many exciting possibilities for VR designers. Even if you foresee the application as single user in the beginning, consider the likelihood you will want to network it in the future. The VR development software you choose will have to be compatible with the network and packet drivers, so find out which ones are supported.

Distribution

The final consideration for software selection is the method of distributing your virtual world. What provisions are necessary if you plan to share the VR application or run it on a computer other than the one used to develop it? In some cases, especially when an interpreted scripting language is used, simulations will not run without a separate runtime module. The module must be installed with the virtual world on the computer that is to run it. Although the cost of the runtime module is usually only a fraction of the cost of the VR development software, it must be added to your budget. Even with packages that let you create stand-alone executables, sometimes you must pay licensing fees before you can distribute the program.

Select the Hardware

When it comes to hardware for the VR application, you obviously want as much horsepower as you can afford. Of course you want a fast and capable processor, but having enough memory is of equal, if not greater, importance. Look at several configurations to come up with the best combination of processor, speed, and memory your budget will allow. As mentioned before, talk to your software vendor to get an idea of what an acceptable hardware configuration would be. Here are some other factors to consider.

Ports and Expansion Slots

Immersive VR systems typically use a lot of peripherals. Viewing devices, tracking sensors, and input devices must all be interfaced to the computer. Many devices connect to a serial port while others require a special card. Consequently, you will need to determine how many serial ports and available expansion slots you will need.

Graphics Options

In order for a computer to generate stereoscopic images, two different views of the virtual world must be rendered for every frame of the simulation. Many graphics accelerators exist which are designed to quickly generate the two images and send them, by way of two separate video signals, to a stereoscopic viewing device. These are commonly used in systems with head-mounted or head-coupled displays which have a separate display panel for each eye. The graphics accelerator you choose will depend upon the software you select since it is written to support specific graphics

BEST COPY AVAILABLE

cards.

Signal Converters

The video signal generated by the computer's graphics card might not be the same type of signal expected by the head-mounted display or other viewing device. For example, you might have a graphics card that generates RGB video signals and a head-mounted display that requires NTSC signals. A signal converter will be needed to make the two devices compatible. If your system generates two video signals, you will need two signal converters.

Head-Mounted/Head-Coupled Display

Deciding on the right immersive viewing device can be an aggravating experience. You should try as many as you can before buying one Unfortunately, the only place you can shop and compare is at a VR conference. Some of the characteristics to consider carefully are the weight and balance of the unit, brightness of the displays, pixel and color resolutions, sturdiness of the enclosure, optics adjustability, field of view, sound capability, and, of course, price.

External Viewing Monitor

When someone else is immersed in a virtual world, you will want to see what they see. Besides, there may be times that you will want to demonstrate the system to a group of interested people. An external viewing monitor allows bystanders to observe what the user sees in the head-mounted display. (Of course, the images on the monitor will not be stereoscopic. Only one of the views will be displayed.) A standard television monitor with a Y cable should be sufficient.

Shutter Goggles

If the system is displaying 30 frames per second, shutter goggles actually depend on two images being displayed for every frame--one for the left eye and one for the right eye. This means your monitor must be capable of displaying 60 images per second (a 60Hz monitor). Some goggles can actually work at 60 frames per second, thus requiring a 120Hz monitor. If you decide to use shutter goggles, make sure you get a monitor with a minimum frequency the goggles require.

Tracking Devices

Although many position tracking systems exist, the most commonly used ones are based on magnetic technology. Magnetic trackers are popular because they track many degrees of movement and the sensors are relatively small. However, magnetic trackers are sensitive to large metallic objects and devices that generate magnetic fields. You must be sure the area in close proximity to the tracker is clear of these objects.

Not all magnetic trackers are created equally in terms of speed. Slower trackers increase the overall lag-time of the system (the delay between the user's movement and the rendering of a new scene on the display). Not all trackers support more than one sensor either. Remember that you must have one sensor for each part of the body that must be tracked.

Sourceless, ultrasonic, and mechanical trackers are other possibilities.

- Sourceless trackers typically use a digital compass to sense the earth's magnetic field, and a liquid-filled inclinometer to sense pitch and roll. (They are called "sourceless" because they do not use a transmitter to emit a magnetic field.) These are 3-DOF devices, so they cannot track full movement. Also, some sourceless trackers are limited in the amount of pitch they

can detect. The user will not be able to look straight up or down if the tracker is used on a head-mounted display.

- Ultrasonic tracking systems track many degrees of movement and have very quick response times. They do, however, depend on a clear line of sight between the transmitter and receivers. With an ultrasonic device tracking head movements, the user must be careful not to turn the head in such a direction that might point the transmitter (on the head) away from the receivers (on the ceiling or a wall).

- Mechanical trackers usually take the form of an arm with one end attached to a viewing device and the other end fastened to a desk or floor stand. Encoders in the joints of the arm quickly and accurately sense the user's movements as the position and viewing angle of the display is changed. This type of system's only disadvantage is that the user is physically encumbered by a rigid arm and can only move within a certain range.

Plan For Success

The addition of a virtual reality lab to your school can provide exciting new possibilities to your educational offerings. Nothing can be more disheartening, however, than the discovery of an overlooked hardware or software item. Unpleasant surprises and disappointments can stall your initial project and even doom your chances of future funding. With careful planning you can avoid these pitfalls and put together a lab that successfully serves you and your students.

About the Author

Tony Gaddis is the Coordinator of Advanced Technology at Haywood Community College's Regional High Technology Center in Waynesville, NC. Among his many duties, Tony writes articles about virtual reality, teaches courses on VR, and manages the college's VR development projects. His e-mail address is: *tony@haywood.cc.nc.us*

He may also be reached at:

Tony Gaddis
Regional High Technology Center
112 Industrial Park Drive
Waynesville, NC 28786
USA

Phone: (704)452-1411 ext. 257

Virtual Reality Courses Taught at Haywood Community College

- **Exploring Literature Through Virtual Reality**
  Literature teachers want their students to become immersed in the stories they read. During the fall term of 1995, "immersion" took on a new meaning for students in Juanita Stock's Major American Writers class. After reading Flannery O'Conner's "A Good Man is Hard to Find," they donned a head-mounted display and stepped into a virtual world based on the final scene of the story. There they found the "tall, dark, and deep" woods; the ill-fated car; the Misfit's glasses; the grandmother's basket in which she hid Pitty-Sing, the cat that caused the accident; the newspaper with the Misfit's picture on the front page, along with some misleading items that were strewn around the scene. Their assignment: walk around, observe the surroundings, and identify the elements of the virtual world that did not appear in the story.

  For the most part, students reacted enthusiastically. They talked about gaining a "new perspective" of a story, of "observing things in a different way," of "a good way to get people more interested in stories," and of a "better way to understand stories." One student said, "There's no comparison between reading from a book and being in the virtual world."

  The results of this experiment were so good that Juanita Stock and Tony Gaddis developed and taught an entire class that blended virtual reality with literature: "Exploring Literature Through Virtual Reality." A visitor to our class might find students wearing 3D glasses while navigating through a stereoscopic projection of John Updike's "A & P," or using desktop VR software in the computer lab to construct a scene from Jack London's "To Build a Fire."

  At the end of the course the students, working in pairs, present their fictional recreation of a short story they have selected. In giving these presentations, students will have had to analyze a story's significant elements: setting, characters, tone and mood, images and symbols, point-of-view. They will assume the role of instructors in their presentations, and, as any educator will attest, teaching is one of the best ways to learn. They will become co-creators of the work in the same sense that movie producers/directors are when they bring literary works to the screen. In working closely with a literary text, they will gain a new appreciation of how writers use words, images, and setting to set a story's tone and mood and to underscore the story's theme. But most importantly, they will become engaged with a literary work on a level none of them have done before.

- **Introduction to Virtual Reality Technology**
  What is virtual reality? What can it be used for? Isn't it just for playing games? These are all questions commonly asked by people who have seen VR portrayed in the movies, but really don't know the truth behind the technology. Haywood Community College is continuing its efforts to answer these questions as it enters its third year of teaching this technology to the general public.

An introductory course, which is taught at the college's Regional High Technology Center, reveals what the exciting field of virtual reality is all about. It provides a careful study of the enabling technologies used to create virtual worlds, an overview of the relevant physiological and psychological factors, and an up-to-date survey of the people and organizations that have made significant contributions to the field. In addition, students get an opportunity to create virtual worlds of their own and to experience immersive VR systems. Because there are no prerequisites, the course is open to anyone with a desire to learn.

The class meets for seven hours each week and engages the students in a variety of activities. Four of the seven hours are dedicated to lively lectures built around multimedia presentations. The remainder of the time is spent in a computer lab constructing virtual worlds with desktop VR software, or in the college's VR lab experiencing immersive VR.

- **Virtual Reality Programming**
  Students who have taken advanced computer programming classes in the Engineering Technology or Microcomputer Systems curriculums have an opportunity to develop virtual reality software from the ground up. This course allows students to develop their programming creativity to its fullest through the creation of specialized desktop virtual reality software.

- **Student Research and Development**
  The Division of Engineering and Applied Technology encourages students to imagine, design, and develop their own virtual reality projects. Credit toward graduation is given for projects that involve the development of hardware and software systems for virtual reality, simulation, and visualization.

Past Projects

- **PowerGlove Modifications**
  The earliest VR project at HCC was the modification of a Nintendo PowerGlove to interface with a standard PC. Students in the Electronic Engineering Technology curriculum built "black box" that allowed the PowerGlove and its ultrasonic position sensors to interface with the PC's parallel port. Software was then used to create virtual worlds where the glove could be used to grasp and manipulate graphical objects.

- **Immersive Walkthrough Engine**
  The first major VR development project undertaken by HCC was a walkthrough engine designed to work with the General Reality CyberEye head-mounted display, 3 degree of freedom tracker, and the CyberStick hand controller. The walkthrough engine is software that runs on a Pentium PC equipped with two Intel i860 graphics cards. The program uses all of these devices mentioned above to immerse a user in a graphical world created in AutoCAD or by other means.

- **The Virtual Computer Lab**
  A plan was established to remove a partial wall and folding room partition in one of the High Technology Center's computer labs. The plan would require the existing computer stations to be repositioned and would free floor space for additional computers. Before any structural modifications were performed, the future lab was modeled by a student using 3D. Once the design was complete, the walkthrough engine (developed earlier at HCC) was used to step into the new lab. The stereoscopic head-mounted display was used to sense the space between tables and workstations.

- **Exhibits**
  HCC has sponsored various exhibits where the virtual reality system was available for the public to try. Long lines always form near the VR station, as people wait their turn to step into Cyberspace.

- **The Virtual Stage**
  The HCC Virtual Reality Lab assisted Spotlights, a local youth drama organization, in the design of a play. On Saturdays, youth from Spotlights met in the High Technology Center's computer lab to model their stage design using Virtus VR software.

Current and Future Development

- **Virtual Safety Training**
  HCC is developing a virtual electronics lab. The lab is equipped with various devices, some safe and some not so safe. The student will step into the virtual lab and identify all the items that are safety hazards. A similar package is also being developed for the Nursing curriculum's home health course. Nursing students will step into the virtual homes of fictitious patients, looking for hazardous items and obstacles to good health care.

- **Wildfire Simulator**
  In cooperation with the NC Forestry Service and the NC Department of Community Colleges, HCC is creating the next generation of wildfire training simulators. The system will use a 3D projection system to display a computer-generated virtual wildfire. The trainees will view the burning landscape through special glasses that make it appear in true 3D. The trainees will make critical command decisions and watch the results as their orders are carried in the simulation.

- **Virtual Manufacturing**
  A virtual manufacturing system is being planned and developed at HCC. The system will simulate a milling machine which students in the Manufacturing Engineering Technology and the Machining curriculums will learn to program. The virtual milling machine software will read the student's programs and simulate, on a computer screen, metal being cut as if it were the real thing. The simulated system will be used to efficiently

troubleshoot programs and save money on metal and wax stock which students normally use to test their designs.

- **The Treatment of Acrophobia Through Virtual Reality**
  The HCC VR Lab is now working in cooperation with a graduate student in the School of Psychology at Western Carolina University in the development of a desktop VR system to systematically desensitize patients suffering from acrophobia (fear of heights). The subjects involved in the study will be immersed in a virtual world in which they will stand in a glass "elevator." The elevator may be controlled to rise a few feet, or several stories. Because the subject will be wearing a stereoscopic head-mounted display, the sense of height will be realistic.

URL's for companies mentioned in this presentation

General Reality Company: www.genreality.com

General Reality sells the CyberEye head-mounted display, CyberTrack 3DOF tracker, CyberStick hand controller, 5DT Glove, and many other items.

Platinum Technology: www.platinum.com

Produces the VRCreator desktop VR software.

Sense8 Corp: www.sense8.com

Sense8 produces desktop and high-end virtual reality software.

Stereographics Corp: www.stereographics.com

Stereographics sells stereoscopic goggles and other devices.

Superscape: www.superscape.com

Superscape produces desktop VR software, including VRT.

Virtual World Wide Web: vwww.com

An collection of 3D web sites, sponsored by Superscape. Requires the Viscape plugin, which can be downloaded.

Virtus Corp: www.virtus.com

Virtus produces desktop VR software, including Virtus Walkthrough and Virtus VR.

Vrex Corp: www.vrex.com

Vrex sells stereoscopic projection systems and goggles.